

for the month of January established when the maximum, 36 miles from the west, was recorded at 2.51 p. m. Owing to the dry condition of the soil the air filled with dust as the wind rose and the sky was entirely obscured by it during the whole afternoon, the disk of the sun being faintly visible only at times. The dust penetrated buildings of even the best construction, leaving a thick coating everywhere. Objects two city blocks distant were obscured. Besides making the day unpleasant, there was damage to wearing apparel, house furnishings, etc. The air was extremely dry and the per cent of humidity decreased to a midsummer minimum by 5 p. m., making the storm particularly damaging to vegetation. In loose, light soils some grain was blown out in places, while in other places it was buried under the wind-transported material. Considerable dust was held in suspension in the air during the 5th and 6th and the sun shone with a sickly light.

This unusual dryness had an important effect in producing the record-breaking freeze on succeeding days. The temperature fell during the 5th, and on the morning of the 6th a minimum of 17° was recorded at this station, 3° lower than the lowest previously recorded minimum in 26 years of record. Standard instruments on the ground recorded 14° and 15° on the 6th and 7th, respectively, and from lower portions of the valley floor readings of 10° and 12° were reported.

Citrus trees and citrus nursery stock were badly frozen, but not entirely killed, except the nursery stock in a few localities. Practically all of the fruit remaining on the trees was completely frozen, a small proportion of the whole crop, as nearly all had been marketed. However, a full year's growth on citrus trees was frozen and will have to be pruned away. Eucalyptus of several varieties, acacias, and pepper trees were frozen severely and the younger trees killed. Ice 2 inches thick formed in considerable volume. A film of ice formed on irrigation ditches in places, a phenomenon which had not been observed here for many years. Much damage was occasioned by frozen water pipes, one plumber alone reporting that 200 calls were made to repair that class of plumbing troubles.

The month closed with some very pleasant but unseasonably warm weather, and the temperature deficiency for the month as a whole is not large. Rainfall for the month was about three-fourths of the normal amount and up to the 31st but one-half of the normal seasonal amount has been received.

REPORT ON RECENT DESTRUCTIVE FROSTS IN CALIFORNIA.

By Prof. A. G. MCADIE.

For many years the Weather Bureau had advised citrus-fruit growers of California that widespread injury might result in unprotected orchards when conditions out of the usual occurred; and that preparation should be made even in the most favored localities for temperatures as low as 24° F. It was pointed out that there had been many dates in the past 35 years when weather conditions were so severe as to cause injury to citrus fruits. The following table shows how frequently such low temperatures have occurred:

1878, Dec. 14.	1889, Jan. 19.	1906, Jan. 1.
1879, Dec. 25.	1894, Jan. 6, 7.	1907, Jan. 2.
1880, Jan. 29, 30, 31.	1897, Dec. 19, 21.	1910, Jan. 6.
1882, Feb. 18.	1898, Jan. 26.	1911, Feb. 16.
1883, Jan. 20, 21.	1901, Dec. 13.	1911, Dec. 25, 26.
1883, Feb. 3, 4, 6.	1902, Dec. 26.	1912, Dec. 23-30.
1886, Jan. 6.	1903, Feb. 14, 15.	1913, Jan. 4, 5, 6, 7.
1888, Jan. 7, 8, 9, 10.	1904, Jan. 21.	

It is somewhat difficult to determine what constitutes a dangerous temperature in connection with citrus fruits, inasmuch as most temperature records have been made in shelters and do not fairly represent the temperature to which fruit is exposed. At San Diego and Los Angeles the recorded values at the Weather Bureau offices are from 5° to 10° above those made in the orange groves a few miles distant, and there appears to be an increase in this difference with distance from the coast. Again, temperature varies with height above the ground and inversions are frequently found during winter mornings. An instrument placed near the top of a tree will generally give a temperature much higher than one placed near the ground. Furthermore, the freezing point commonly used is not necessarily the freezing point for water in the plant. Finally, injury is probably determined more by the rate of warming up after the blossom or fruit has been subjected to a freezing temperature than by the fall in temperature. In other words, defrosting is a matter of the utmost importance.

Oranges and lemons are commercially grown in Florida and in portions of Louisiana, as well as in California; but the extent of the industry in California may be judged from the following table, which shows the shipment of citrus fruit from the whole State for the past 19 years:

Season.	Carloads.	Season.	Carloads.
1894-95.....	7,575	1904-5.....	31,422
1895-96.....	6,915	1905-6.....	27,610
1896-97.....	7,350	1906-7.....	29,820
1897-98.....	15,400	1907-8.....	32,729
1898-99.....	10,875	1908-9.....	40,516
1899-1900.....	18,400	1909-10.....	33,099
1900-1.....	24,900	1910-11.....	46,594
1901-2.....	19,180	1911-12.....	36,283
1902-3.....	23,875	1912-13.....	
1903-4.....	29,399		

The above data are in the main from the California Fruit Grower.

On December 24, 1912, the crop was estimated at 48,000 carloads. Within a week from this time the injury had been so great that now no reliable estimate can be made. A somewhat similar condition occurred during the preceding year. Estimates of the crop of 1911-12, made previous to the frost of December 25-26, made the crop 50,000 carloads. It is generally conceded that the money loss caused by the frosts in the closing week of 1911 amounted to \$5,000,000. The loss during the last week of December, 1912, and the first week of January, 1913, may exceed \$15,000,000.

In both of these periods ample warning of the fall in temperature was given, and in some localities intelligent and well-directed effort was made to prevent the lowering of the temperature. This was particularly the case at Pomona, where the orchardists are organized under the lead of Mr. J. E. Adamson, in a protective association. The methods employed were described in the Monthly Weather Review for July, 1912. Reports are received hourly, or oftener if necessary, during the early night at a central station, and a tag for each report is placed upon a large map of the district in its proper place. It is thus possible to estimate the rate of change in temperature; and to order the necessary firing, which is done by the force under the direction of the general manager. Records show a rise in temperature of 6° one hour after firing.

The protective devices used are oil burners of simple construction, the fuel being a low grade of distillate. As originally used, these burners did not consume all of the carbon, but gave off a soot-laden smoke. The soot has been found to be not only extremely disagreeable,

but detrimental, and in fact it is necessary to wash the orange to remove the soot. The more modern burners provide better combustion and as used during the present frost periods were more effective than the old-style open pot. As will be shown later, there was an extremely low humidity during the present frost, and it became evident that in addition to heat there must be provided a supply of water vapor. A simple and economical form of heater which seems to meet these requirements is described in the Monthly Weather Review for April, 1912 (p. 618).

The frost periods under discussion differ from the frosts of December 25-26, 1911, in that the strong winds preceding the frost came apparently from the north and northwest rather than as usually happens from the northeast. It would appear that instead of the usual draft through the Cajon Pass, elevation 3,823 feet, the winds came over the Sierra Madre—i. e., over a range with elevations exceeding 6,000 feet. Such air descending would be somewhat drier than air passing through the pass. While accurate records of air motion are not available, some unusual conditions were noted. On January 3 it was a matter of general comment in the valley that the norther began in the west, the wind blowing first from the west, or even southwest, and then veering to the north. It was also noted that the wind began at Wineville earlier than at Riverside and blew hard for an hour, followed by a calm at Wineville, while high winds prevailed in other sections.

A detailed description of the valley can be found in the Monthly Weather Review for December, 1910. The Sierra Madre crosses California, running east and west, 200 miles and more. A portion of the range is known as the San Gabriel Mountains and extends from the Santa Clara River to the Cajon Canyon. Another portion of the range is known as the San Bernardino Mountains and extends from the Cajon Pass eastward to the headwaters of the Santa Ana River. Some of the high peaks are: San Gabriel, 6,152 feet; Mount Wilson, 5,886 feet; Sugar Loaf, 7,006 feet; Ontario, 8,752 feet; Cucamonga, 8,911 feet; North Baldy, 9,000 feet; San Antonio, 10,080 feet; San Bernardino, 10,630 feet; and San Gorgonio, 11,485 feet.

During frost periods the air drains slowly to the southwest from Nevada; also south through the Owens Valley in California. Crossing the Mojave Desert, the surface air ascends the northern slopes of the Sierra Madre and descends into the San Gabriel Valley. The normal drainage in the valley is from northeast to southwest during the morning hours, with a return current during the afternoon hours. Wind effects are marked near the passes. High winds often blow across the valley from the Cajon Canyon to the Jurupa Mountains, a small range not exceeding 2,260 feet, lying northwest of Riverside. The Santa Ana River drains much of the valley, and the channel of this river, the extensive washes and the numerous hills and minor ranges all play a part in influencing the air drainage of the valley. There are well-marked frost belts and these in general are in the wind-sheltered areas. The descending air is both dry and dust-laden. When the wind lulls, the soil, mostly river wash, coarse sand, gravel or sandy loam, loses heat rapidly by free radiation. During the still hours of the night and before the return flow of moisture laden air from the sea can be effective, the temperature falls rapidly.

The following tables give the minimum temperatures recorded at a number of points in the valley from December 24, 1912, to January 8, 1913.

It will be noted that a minimum of 28.4° occurred at San Diego at 4 a. m., January 6, and 24.9° on January 7,

at 6.15 a. m., breaking all records for minimum temperatures at that station.

Minimum temperatures, December, 1912.

Stations.	24	25	26	27	28	29	30	31
Azusa.....	24	31	32	41	34	32	34	34
Beaumont.....	44	34	42	43	33	35	42	41
Chino.....	32	28	28	28	30	28	28	30
Claremont.....	34	32	33	30	32	36	37	37
Colton.....	34	36	34	33	33	32	33	38
Duarte.....	34	32	37	45	38	38	37
Escondido.....	25	24	50	30	23	24	28	27
El Cajon.....	26	25	27	31	24	27	30	29
Los Angeles.....	45	38	43	46	45	46	47	43
Monrovia.....	34	32	35	40	40	38	36	38
Orange.....	29	32	32	32	28	30	30	33
Pasadena.....	33	30	32	31	31	33	36	36
Pomona.....	28	26	26	26	28	30	30	29
Redlands.....	33	32	29	29	31	33	36	35
Riverside.....	28	26	34	32	27	30	33	32
San Bernardino.....	25	26	36	24	25	27	32	31
San Diego.....	42	42	44	46	43	43	42	39

Minimum temperatures, January, 1913.

Stations.	1	2	3	4	5	6	7	8	9	10
Azusa.....	38	40	52	33	25	22	20	26	33	33
Beaumont.....	35	34	32	29	20	16	24	32	34	34
Chino.....	28	28	30	30	30	28	16	16	22	22
Claremont.....	37	39	44	37	27	25	19	26	35	34
Colton.....	43	45	44	36	28	27	19	27	36	38
Duarte.....	41	45	55	40	28	28	27	39	37
El Cajon.....	39	38	34	34	30	20	21	19	28	38
Escondido.....	39	40	37	29	32	15	13	18	26	35
Fresno.....	38	35	33	31	24	17	20	27	32	32
Los Angeles.....	47	45	55	43	36	30	28	36	40	39
Monrovia.....	42	38	40	30	28	24	18	19	38	34
Pasadena.....	40	40	44	36	31	25	21	25	35	34
Pomona.....	41	36	36	29	25	21	18	22	36	30
Redlands.....	35	42	42	39	31	22	18	24	34	36
Riverside.....	36	43	37	32	30	21	22	22	33	36
San Bernardino.....	30	44	35	32	31	26	18	19	32	34
San Diego.....	48	48	51	46	36	28	25	34	41	39

The lowest temperatures occurred on the morning of January 7, although on the morning of the 6th and the morning of the 8th dangerously low temperatures were recorded.

The general weather conditions on the morning of January 7 were as follows: A well-marked area of high pressure overlaid the Great Basin and the southern half of the Pacific slope. The pressure was also unusually high over the Rocky Mountain section, the Missouri Valley, and Manitoba. A well-marked disturbance overlying the Mississippi Valley was accompanied by cloudy weather and rain or snow over the entire country east of the ninety-fifth meridian. The isotherm of freezing temperature extended from the west gulf coast northeastward to the Ohio Valley and thence to New England.

The pressure of distribution was typical for frost in southern California. Study of the weather maps from January 3 to January 12 will show that there was a progressive increase in the severity of the weather from Friday afternoon until the following Wednesday. On Saturday, January 4, brisk winds began shortly after noon and continued until 3 a. m., January 6. Attention is directed to the marked effect of this brisk wind upon the temperature. During the midday hours on the 4th, 5th, and 6th the temperature did not rise much above 50°, and in some places did not reach 50°, or thirty degrees lower than the normal midday temperature. This strong wind would undoubtedly have had a beneficial effect and prevented rapid cooling had the air been stratified and the usual distribution of heat existed. On the contrary, the whole mass of air to an elevation of possibly several thousand feet was at a low temperature. If a comparatively warm stratum existed a short distance above the

ground, it was not of sufficient thickness to materially raise the temperature. The thermograph records from noon, January 5, until midnight are significant. For some as yet unexplained reason there was a rise in temperature of 6° between 10 p. m. and midnight of January 5. There was also a peculiar fluctuation in the moisture content of the lower air. The wind produced a marked drying effect and for a period of nearly 96 hours the curve showing percentage of saturation is quite unlike the curve usually given during frosts in these localities. The usual conditions are still, quiet nights when the minimum is determined primarily by free radiation. As a rule there is little air motion in these localities at times of frost and as any loss of heat by convection is small, it would appear that during the interval referred to above, while air motion was active large volumes of comparatively cold air, i. e., as cold as the radiating surface, if not colder, passed over and through the orchards. The character of the radiating surface is of course of great importance, perhaps of as much importance as the exposure. Doubtless some of the apparent inconsistencies reported may be due to convective gains on the one hand and interference with free radiation on the other, both contributing to keep the temperature higher than would ordinarily be the case. The data collected are insufficient to establish the height of the level of lowest temperature. It is also a matter of regret that instruments for continuous and detailed records of wind velocity and direction are not available.

In general the citrus fruit was subjected to temperatures below freezing for four successive periods, averaging 4 hours for the first, 4 hours for the second, 13 hours for the third, and 9 hours for the fourth. In all it may be said that in a total period of 72 hours during which under normal conditions the plants would have received a supply of heat approximately represented by 1,500 hour degrees, starting from a temperature of 40° F., they received only 220 hour degrees. There were 170 hour degrees below freezing and of these 50 were below 25° F. In a general way there were 30 hours when the temperature was below freezing; 12 hours when it fell as low as 25° F., and 2 hours when the temperature did not exceed 20° F.

Of the many reports which have been submitted, a few have been selected and are given below:

Riverside, Cal., February 6, 1913.—A month has passed since the frost. Regarding the section in West Riverside, which we inspected together, I find that the lemon grove shows considerable injury on the lower half. However, there is practically none of the wood injured, the injurious effects being confined to the leaves and fruit. Most of the trees retain one-half of their leaves. Upon the higher levels there is very little damage, although some of the fruit undoubtedly is injured. Upon sections which seemed clear when you were here, I picked blossoms a week ago which had opened since the frost, also saw small lemons a quarter of an inch in diameter which had not been injured. A considerable section, from 10 to 25 acres, shows no injury. The grape fruit on the high level to the south is also unhurt as to fruit and leaves. The grove of S. L., about a mile from the lemon grove, looks practically uninjured. Mr. L. admits there is considerable damage to this fruit on the lower levels; but not so much as a year ago and he is confident of marketing a good proportion of the fruit. The grove above the road shows no greater damage than it did when you were here. A section a little over a mile wide west from the Golden West lemon grove shows less damage than the balance of the Riverside Valley. Some of the groves are entirely free from injury

as to fruit and leaves. Bloomington and Rialto show a number of groves which from the street seem practically unhurt and without doubt there are many sections through these neighborhoods where much uninjured fruit will be harvested. Undoubtedly it is true that this section of West Riverside and a strip through Bloomington and Rialto were injured much less than a year ago and very much less than the balance of the valley, and, further, a great many trees in various parts of this strip escaped injury entirely from this frost.

It is conceded that the lowest general temperature of the first night, January 5 and 6, did practically no damage to most of this section, and that the third night was really more harmful to this locality than the first night.—Dr. C. VAN ZWALENBURG.

Upland, Cal.—The greatest damage was done on Monday night (the 6th) and Tuesday morning (the 7th). There are 1,000 trees on my 10-acre ranch. There was one 1-gallon oil pot to each tree. Heretofore I never had to fire before midnight and the equipment was sufficient to amply protect. On that Monday night water froze at 6 o'clock. I had to stand and take it, knowing that if I lighted before 12 the pots would go out too soon; but at 10.30 p. m., I started lighting and finished by 1 a. m. Began observations at 4 a. m., when it was 20° outside the grove and 28° inside, thermometer placed as far from a pot as I could get it and the same thermometer used. At 5 a. m., the temperature outside was 20° and inside 26°. At 6 o'clock outside temperature 20°, inside temperature 23°. The fires soon went out for lack of oil and the temperature remained near 20° until 7 a. m., and not above 32° until 9 a. m. If I had had four 1-gallon pots to the tree and lighted one at 6, one at 10, and the other two at 2 o'clock, I think I would have saved my crop. I think I have saved some of it as it is. I am not sure but that more heat can be obtained from 1 gallon of stove distillate at 9 cents than from 3 gallons of the slop distillate at the same cost. There should be a burner under every tree and enough distillate stored in the reservoir under the tree to last the season. It is this filling of the pots the next day that kills; also it is very expensive. Under the tree the leaves would prevent the loss of heat by radiation. While the smoke is objectionable in many ways and especially to the community, it must be beneficial in preventing radiation from the earth.

On another 10-acre plot I have the Exchange single-stack pot. There are 690 trees and 690 pots. The trees are 27 feet apart. Temperature results were about the same as above. The pots hold 3 gallons, but are filled to 2½. More oil is used, but the trees are further apart and so heat is lost. The pots last about 7 hours, but as the stack makes a big draft there is waste of oil. The pots went out a little too early that night.—F. C. CROWELL.

Glenville.—The sand storm that raged in the valley on the 4th and 5th did not reach here and we appeared to be above the wind. The first we knew there was a storm raging about 4 p. m., on the 4th, when a cloud drifted in that we thought was fog but proved to be dust. On the 5th it was calm, but the dust hid the sun nearly all day and the air was filled with it for three days afterwards. It settled on everything and was enough to change the color of the shrubbery and ground.

The cold wave that followed was quite severe. The thermometer registered 9° at this station; but 1 mile east and 400 feet lower on the creek bottom they claimed it was 2° below zero.—C. H. LIKELY.

El Cajon.—On the 5th the thermometer registered 35° at 5 p. m., 30° at 6 p. m., and 32° at 6.30 p. m., and fell to 20° during the night. Oranges frozen solid on this and the following two nights. No smudging. Ice remained unfrozen for three successive days. Coldest on record.—H. H. KESSLER.

Pomona.—On the mornings of the 7th and 8th the temperatures outside of the smudge area, but at the same elevation, registered 15° and 18°, respectively.—J. E. ADAMSON.

Squirrel Inn.—The sand storm from the desert on the 4th was terrific, the valley was entirely obscured.—A. D. FRANTZ.